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Education

- **University of Delhi**, Department of Physics & Astrophysics, Delhi, India, **Ph.D.** in Experimental Particle Physics, March 2007
  Thesis: Tests of QCD in p-p Interactions at 14 TeV.
  Advisor: Professor Ram K. Shivpuri
- **University of Delhi**, Department of Physics & Astrophysics, Delhi, India. **Master of Science (Physics)**: 1998-2000, First Division.
- **University of Delhi**, Delhi, India, **Bachelor of Science, Physics (Hons)**: 1995-98, First Division.

Research Fields

Experimental High Energy Physics and Grid Computing.

RESEARCH EXPERIENCE

Work in Progress

CDF Experiment

CDF stands for the **C**ollider **D**etector at **F**ermilab. CDF is an experiment at Fermilab, which is currently home to the world's most powerful particle accelerator called the Tevatron. The Tevatron accelerates protons and antiprotons close to the speed of light, and then makes them collide head-on inside the CDF detector. The CDF detector is used to study the products of such collisions; by doing this we try to reconstruct what happened in the collision and ultimately try to figure out how matter is put together and what forces nature uses to create the world around us!

Physics Analysis

Search for Quark Compositeness Using Dijets

The standard model gives a good description of nature in terms of the fundamental fermions and their interactions via gauge bosons. However, the SM is not expected to be a complete theory. For example, it doesn't explain the number of fermion families or their mass hierarchy. It also doesn't provide a unified description of all gauge symmetries. Compositeness models postulate constituents of the SM fermions and new strong dynamics that bind these constituents.

We are using dijet mass differential cross section for search of compositeness. The measurement of the dijet mass differential cross section is also sensitive to the presence of new high mass particles decaying into dijets. Many classes of particles in beyond the standard model scenarios have a larger branching fraction into two partons (quarks and gluons) than into modes containing leptons, photons and electroweak gauge bosons, and they are expected to make a resonant structure in the dijet mass spectrum. Searches for compositeness in the dijet mass spectrum is challenging due to a large contribution from direct two-jet production via quantum chromodynamics interactions; however, the previous observation of W and Z bosons decaying into dijets by the UA2 Collaboration showed the feasibility of finding dijet mass resonance at hadron colliders. **Abstract submitted to APS 2009**.

Estimation of Heavy Flavor content in Minimum Bias Sample

In hadron collisions, while hard interactions are theoretically well defined and described as collisions of two incoming partons along with softer interactions from the remaining partons (the so-called "underlying event"), minimum-bias (MB) interactions may be defined only through a description of the very inclusive trigger that experimentally collects them. A MB dataset contains in principle all types of interactions which is proportional to their natural production rate. At Tevatron energy, it consists largely of the softer inelastic interactions. The understanding of softer physics is necessary for precision measurements of hard interactions where soft effects need to be subtracted. MB physics offers a unique ground for studying both the theoretically poorly understood softer phenomena and the interplay between the soft and the hard perturbative interactions. The description of these events requires a non-perturbative phenomenological model. Moreover, min-bias triggered data gives us information which are unbiased in nature.

We are trying to understand the contribution of heavy flavor(HF) hadrons in the minimum bias sample. The CDF collaboration has developed heavy flavor tagging algorithm (Jet Probability Heavy Flavor Tagger Algorithm) which is especially suited for high p_T jet. In our case, the jets from heavy flavor quarks are of low p_T and it is not feasible to reconstruct these jets. We modified the original CDF jet probability heavy flavor tagger algorithm and found that the parameters of modified algorithm can be used for HF tagging in minbias data. The original heavy flavor tagger algorithm runs on the production data. It will take significant amount of CPU power and

disk space to process the production data. We decided to use the more condensed format of production data (Stntuple) in order to minimize the amount of CPU power and disk space. The Stntuple don't contain all the information needed for running the original b-tagging algorithm and it needs some modification in our case. During the past months, we re-wrote the b-tagging algorithm for our case and presently understanding its performance. **Analysis is under progress**.

Grid Computing: SAM-SRM Interface for Movement of MC Data

The CDF experiment has generated more than 4 fb^{-1} of real data. We need Monte Carlo(MC) data for detector understanding and physics analysis. It is not feasible to produce these MC data on-site due to limitation on computing resources. The CDF remote sites or Grid Tier1 and Tier2 can be utilized for producing MC data. From our past experience, we learnt that one of the most important limitation in the heavy usage of off site resources is that the Worker Nodes(WN) were sitting idle for several hours just because another WN was transferring data to Storage Element(SE) at Fermilab. This situation leads to inefficient uses of computing resources and sometimes to the loss of the output from the worker node. Moreover, how to face the problem of sudden arrival of MC output data from different remote sites at same time to the SE at Fermilab. We found that this causes overloading of available file-servers and leads to failure of data handling part of MC production.
This rises the question on how to manage the transfer of produced Monte Carlo samples from remote Grid sites to FNAL in an efficient way; up to now CDF has relied on a non scalable centralized solution based on dedicated data servers accessed through rcp protocol, which has proven to be unsatisfactory.
We proposed a framework for transportation of MC data from remote sites to Fermilab. This framework relies on integration of **S**equential data **A**ccess via **M**etadata(SAM) with Storage Resource Manager (SRM). We used SAM because it is the default data handling framework of the CDF. The reasons for using SRM are to avoid unnecessary complications which may arise from different Storage Elements (SE) at different remote sites. At present, I am studing the performance gain and the benefits of the new framework in comparison with the old approach. **Abstract accepted to CHEP 2009**.

Work Completed

CMS Experiment

SISCone Jet Clustering Algorithm

Current cone jet algorithms, widely used at hadron colliders, take event particles as seeds in an iterative search for stable cones. A longstanding infrared (IR) unsafety issue in such algorithms is often assumed to be solvable by adding extra 'midpoint'

seeds, but actually is just postponed to one order higher in the coupling. A proper solution is to switch to an exact seedless cone algorithm, one that provably identifies all stable cones. The Seedless Infrared-Safe Cone (SISCone) jet algorithm is a cone clustering algorithm which is reasonably fast, infrared safe to all orders in the perturbative expansion, and this is theoretically sound. We compare the performance of the Seedless Infrared Safe Cone (SISCone) jet clustering algorithm with the Midpoint algorithm for jet reconstruction in CMS calorimeters. It is shown that reconstructed quantities are similar for the two algorithms and they have similar performance for multijet processes such as top production. *We propose that SISCone be adopted as the default cone based jet clustering algorithm for CMS.* **Published in CMS AN 2008/02**.

CMS sensitivity to Contact Interactions using Dijets

The replication of fermions families along with the mass hierarchies and mixing has led to one to speculate about the possibility of quark-lepton compositeness, namely that the Standard Model fermions are not elementary at all. The fundamental matter constitutes in such theories, very often termed *preons*, experience an hitherto on account of asymptotically free but confining gauge interaction, which would become very strong at characteristic scale Λ hereby leading to bound states (composites) which are to be identified as quark and leptons. When Λ is out of direct experimental reach, the propagator in the intermediate state effectively shrinks to a point, yielding a contact interaction. This is true regardless of the source of the new physics. The most common example of physics behind contact interactions is quark compositeness. It is therefore a powerful first signal of new physics, which we should expect to observe before the new particles could be directly produced and detected at LHC.
We study CMS sensitivity to quark contact interactions in the dijet final state using the new CMS software framework for simulation and reconstruction (CMSSW). The canonical model of a contact interaction given by Eichten, Lane and Peskin has been considered. Dijet angular distributions reflect the dynamics of the hard scattering of quarks and gluons, and are expected to be fairly insensitive to the momentum distributions of these partons within the proton. Measurements of the dijet angular distributions can help in resolving whether the measured excess of events with high E_T jets is a signal of new physics or merely new information on the ingredients of the QCD calculations. The contact interaction signal and QCD background are estimated for the dijet ratio as a function of dijet mass from 0.3 to 6.5 TeV. Statistical uncertainties are estimated for integrated luminosities of 10 pb^{-1}, 100 pb^{-1}, 1 fb^{-1}, and 10 fb^{-1}. The χ^2 between the background and the signal is estimated, including systematic, and is used to find CMS sensitivity to the contact interaction scale Λ. For an integrated luminosity of 10 pb^{-1}, 100 pb^{-1}, 1 fb^{-1}, and 10 fb^{-1} CMS can expect to exclude at 95% CL a Λ value of $3.67, 6.561, 11.51$, and 14.31 TeV or discover at 5σ significance a Λ value of $2.69, 4.703, 8.694$, and 12.81 TeV, respectively. **Published**

in CMS AN 2007/015 and **J. Phys. G36:015004,2009**.

Monte-Carlo Production

The CMS experiment had released new framework for simulation and reconstruction software. In order to validate each new release of simulation and reconstruction packages of CMS (CMSSW), large statistics of Monte-Carlo samples are required. The Monte Carlo sample for W+Jets was generated and validated using new releases of CMSSW at LHC Physics Center (LPC), FNAL. While simulating W+Jets events, different decay modes of W were considered in keeping with the needs of other Physics Group.
At nominal design luminosity ($10^{34} cm^{-2} s^{-1}$), LHC is expected to deliver on average about 17 proton-proton interactions per beam crossing. There are contributions both from particles produced in a trigger (in-time pileup) and from particles produced in the adjacent crossing (out-of-time pileup). Pileup of particles from different interactions will produce energy clusters in the calorimeter which can be misidentified as jets. The effect of in-time and full pileup has been studied on jet pseudorapidity. From pileup study, we concluded that the samples which are needed for jet studies should contain in-time as well as out-of time pileup. **Published in CMS IN - 2007/053**

Optimization of Transverse Shaping of Lead Absorbers in the CMS Preshower

Physics at the Large Hadron Collider (LHC) requires extremely high performance detectors. The Compact Muon Solenoid (CMS) electromagnetic calorimeter (ECAL) has been designed to facilitate the discovery of the Higgs Boson. The most stringent requirements imposed on the electromagnetic calorimeter (ECAL) are from two photons decays of the intermediate mass Higgs Boson. But there are significant amount of background from the decay of pions into two photons. The Preshower in the CMS detector is incorporated to reject neutral pions in the endcap. The basic structure of the Preshower devices used in CMS are two layers of a dense absorber material (lead) followed by a Silicon microstrip detector plane. The precise shaping of the lead absorber in the transverse direction was still to be resolved. It was the requirements that all lead must be covered by Silicon sensors but it was unclear as to whether the lead should be shaped to follow the outline of the sensors or indeed to follow the outline of the crystals that are behind the Preshower.
The CMS Object-oriented (CMSOO) software is used for detailed simulation and analysis for transverse shaping of lead absorbers in the CMS Preshower. It has been concluded from the above studies that shape of Lead will follow according to dimensions of crystals in the ECAL endcap at lower eta ($\eta = 1.653$) and circular at higher eta ($\eta = 2.6$). This design of Lead absorbers in CMS preshower will improve the low p_T physics potential of CMS experiment at LHC. **Results has been cited in CMS Detector Physics TDR, Vol. - I (Page No. 150)**

Direct Photon Production at LHC

Study of direct photon in high energy hadronic collisions provides a clean tool for testing the essential validity of perturbative QCD predictions as well as for constraining the gluon distribution of the hadrons. Studied in detail the characteristics of single direct photon production in the kinematical regions accessible at LHC regime. Presented the Leading order and Next-to-Leading order QCD predictions for direct photon cross section at $\sqrt{s} = 14$ TeV as a function of transverse momentum of photon (p_T) in the kinematical region 20 GeV $< p_T <$ 400 GeV and $|\eta| < 3$. The work also demonstrates the sensitivity of the theoretical predictions to the choice of renormalization scales and gluon distributions. The pseudorapidity and cone sizes dependence of the direct photon cross-section was also discussed. **Published in Phys. Rev. D., 67, 014016, Jan. 2003**.

k_T Effect in Direct Photon Production

Studied parton k_T smearing in direct photon production at Tevatron centre of mass energy. Previous detailed studies of direct photon production from both fixed-target and collider experiments have witnessed a pattern of deviation between measured inclusive cross sections and the corresponding theoretical expectations for the transverse momentum (p_T) distribution. Most data sets display steeper p_T dependence than the next-to-leading-order (NLO) perturbative QCD (PQCD) calculations with standard choices of scales and parton distribution function in the low p_T region. A simple implementation of higher-order soft gluon corrections to the NLO PQCD predictions through parton kT smearing significantly improves the agreement between data and the theory. This attractive consideration provided the motivation to investigate the CDF and DZero measurements of inclusive photon cross-section at $\sqrt{s} = 1.8$ TeV from the Run 1 and also at $\sqrt{s} = 630$ GeV. We have found that the implementation of parton k_T smearing effects in the NLO calculations provides a much more acceptable description of the Tevatron data in the low p_T region. **Published in Phys. Rev. D., 68, 014017, July 2003**.

COMPUTER SKILLS

- **Knowledge of operating system**: Sun Solaris, Linux and Windows.
- **Knowledge of computer programming languages**: C++, Python, Java, XML, Shell script, Fortran.
- **Knowledge of debugging tool**: Valgrind.
- **Conducted the Simulation Workshop** for CMS, $16^{th} - 24^{th}$ Feb., 2004, held at the Center for Detector & Related Software Technology, University of

Delhi, India. The participants included **post-doctoral fellows, graduate students, system managers** and **software experts** from Tata Institute of Fundamental Research (TIFR) Mumbai, Panjab University & Delhi University. The participants learnt the installation of CMS software and their use in physics analysis.

- **System Administrator**: I was the system administrator for University of Delhi, High Energy Physics group from 2000 - 2006.

IMPORTANT TALKS

1. **"Monte Carlo Data Motion"** in CDF grid Workshop at Fermilab on Jan. 14^{th}, 2008.
2. **"Dijet Ratio Status"** in Early CMS Physics Workshop at Fermilab, from 8^{th} to 9^{th} June, 2007.
3. **"Dijet Ratio from QCD and Contact Interactions"** in combined QCD and SUSY/BSM working group, at Fermilab, on 18^{th}May, 2007.
4. **"Study of jets in W + jets"** in in LPC physics group at Fermilab, on 11^{th} Jan. 2007.
5. **"Optimization of Transverse Shaping of Lead Absorber in the CMS Preshower"** in CMS Week at CERN from 14^{th} to 30^{th} March, 2005.
6. **"Direct Photon Production at The LHC"** India-CMS Collaboration Meeting held on 25^th Jan, 2002 at Panjab University, Chandigarh.
7. **"Inclusive Jet Cross-Section at 1.8 TeV (DZero)"** in India-CMS Collaboration Meeting held on 20^{th} March, 2003 at Delhi University, Delhi.

CONFERENCE/WORKSHOP/SCHOOL ATTENDED

1. **INFN Grid Computing School**, held at INFN Bologna, Italy from 6^{th} to 9^th Oct. 2008.
2. **CTEQ Summer School on QCD Analysis and Phenomenology**, held at University of Wisconsin, Madison from 30^{th} May - 7^{th} June, 2007.
3. **Workshop on Computing in High Energy Physics (CHEP)**, held at Tata Institute of Fundamental Research, Mumbai from 13^{th} - 17^{th} Feb., 2006.
4. **Simulation Workshop for CMS**, $18^{th} - 20^{th}$ Feb. - 2002, held at Ooty, India.

5. **Workshop on CMS at LHC** held at Tata Institute of Fundamental Research (TIFR), Mumbai (Dec. 2000).

HONOURS, AWARDS, FELLOWSHIP

- **Post Doctoral Fellow** at "INFN in the CDF experiment at Fermilab" from September 2007 - present.
- **Visiting Scientist** at "Fermilab, Batavia, USA" to collaborate on the CMS physics and simulation from October 2006 - June 2007.
- **Scientist** at "Center for Detector and Related Software Technology (CDRST), Department of Physics, University of Delhi", on the project "Search for new particles at Large Hadron Collider at CERN, GENEVA", June 2005 - June 2007.
- **Senior Research Fellow**, Council of Scientific and Industrial Research (CSIR), Govt. of India, July 2002 - May 2005.
- **Junior Research Fellow**, CSIR, Govt. of India, July 2000 - June 2002.
- Awarded University Grant Commission, **National Scholarship at the Centre of Advance Studies**, Department of Physics & Astrophysics, University of Delhi, 1998 - 2000.

REFERENCES

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- Dr. Robert M. Harris
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- Dr. Kenichi Hatakeyama
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